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Abstract

The pairing of Information Technology (IT) and the environment, under the headline of Green IT, has given rise to a near-endemic concern on how Green ITs themselves are and on how IT can enable a business's Green strategy. However, Green IT is neither a well defined concept, nor a single innovation, nor a uniformly accepted set of practice. This ambiguity has an implication in advancing Green IT research, as it affects the definition of the dependent and independent variables. This paper proposes a framework that can assist in the conceptualisation of Green IT and the definition of the Green IT phenomenon. The framework is partially tested using data from a survey of 143 Chief Information Officers and IT managers and employing principal component analysis. With the findings, the study makes an original contribution, albeit preliminary, to the definition and operationalisation of Green IT in a given research context. Practitioners can use the framework to chart out different strategic options in Greening their IT.

Keywords: Green IT, Green IS, Reach, Richness, Computing, Sustainability

INTRODUCTION

The integration of Information Technology (IT) with the environment has a long tradition. Research on the pairing of ITs and the environment, normally referred to as "Enviromatic", has traditionally focused on IT applications that capture, simulate, process and disseminate heterogeneous and often remote data from environmental objects to facilitate environmental management and planning (Avouris and Page 1995; Green and Klomp, 1998). Thus, the development and utility of a broad spectrum of environmental information systems such as geographical information systems, monitoring and control, computational evaluation and analysis, planning and decision support systems have been researched (Avouris and Page 1995; Green and Klomp, 1998; Huang and Chang, 2005). The dominant perspective in such line of enquiry is the "computational" meta-concept of IT (Orikowski and Iacono, 2001). Hence, ITs and their systemic power for multidimensional and multi-scale data analysis and environmental system modelling are seen as catalysts for sustainable development strategies (Huang and Chang, 2005).

Recently, the pairing of ITs and the environment, under the headline of Green IT, has given rise to a near-endemic concern on how sustainable ITs themselves are and on how ITs enable a business's sustainability strategy. Although the term "Green IT" is becoming more common in discussion, there is little common understanding of what this term actually means. There are ambiguities surrounding both the "Green" and the "IT" in Green IT. Such ambiguities in the understanding of what constitutes Green IT can deter the development of a cumulative Green IT research. Given that historically the information systems (IS) research has been criticised for not paying sufficient attention to and lacking deep engagement with the IT artefact (Orikowski and Iacono, 2001), there is a need for a sound understanding of the domain constructs of Green IT. As Green IT is a relatively recent research field, its advancement as a research field requires theorisation, model construction, and measurement development (Hair et al. 2006). For any field of study to progress in theorisation, clear definition of a construct is an essential first step (Pankaj et al. 2009).

The aim of this paper is to further the understanding of Green IT and aid the process of theorisation and model construction. To achieve this aim, the paper proposes and empirically validates, albeit partially, a Green IT Reach-Richness framework. The framework can be used in carving out a definition of Green IT suitable to a particular research context, providing consistency in future Green IT research. The framework further shows the multidimensional nature of Green IT. Practitioners can use the framework to chart out different strategic options in Greening their IT. Despite these contributions, the study can only be considered as preliminary and leaves ample room for future refinements and improvements.

The paper begins with a review of extant academic Green IT literature. This is followed by the conceptual framework leading to a discussion of data collection and findings. The paper concludes with implications for further research.

THE "GREEN" AND THE "IT" IN GREEN IT

Green IT has drawn not only the attention of business organisations, regulators and environmental groups but also that of IS researchers. A number of concepts are used in the pairing of "Green" and "IT" among IS researchers. On the Green side, while some use "sustainability" (Elliot 2007; Elliot and Binney 2008; Maruster et al 2008; Schmidt et al, 2008) and others "eco-sustainability" (Chen et al. 2008; York et al, 2009), the rest prefer "Green" (Murugesan, 2008; Molla et al 2008; Molla 2008). Likewise, IT, Information Systems (IS) and Information and Communications Technologies (ICTs) are used sometimes interchangeably (Capra and Merlo, 2009; Elliot, 2007; Elliot and Binney 2008) and at other times differently (Chen et al 2008; York et al, 2009). A few prefer Green Information Technologies and Systems (Jenkin and McShane, 2009). In the remaining part of this section, the concepts of "Green" and "IT" are discussed in detail.

The Green movement represents a significant social movement and a general reaction to the malfunctioning of the Western social formation (Galtung 1986; Mathur and Mathur 2000). It incorporates many aspects of everyday life such as ecological balance, politics, consumerism, technology, product purchases and consumption, marketing, manufacturing and resources (Mathur and Mathur 2000). In the context of business, various interpretations of a "green business" are offered (Walley & Taylor, 2005; Schendler, 2002; Hart, 1995). A green business could be one that is set up on "green basis" or one that has become relatively green (Walley & Taylor, 2005). Greening refers to a process towards sustainability. There are many interpretations of sustainability (Starik & Rands, 1995; Hart, 1995). For example Starik and Rands (1995) define sustainability as "the ability of one or more entities, either individually or collectively, to exist and thrive (either unchanged or in evolved forms) for lengthy timeframes, in such a manner that the existence and flourishing of other collectivities of entities is permitted at related levels and in related systems" (Starik and Rands, 1995:909). The conceptualisation that is relevant to the analysis in this paper is eco-sustainability.

Ecological sustainability is generally concerned with minimising emissions, waste and water, improving efficiency and minimising the total environmental footprint of a business (Hart, 1995). It often refers to meeting the needs of present generations without compromising the ability of future generations to meet their needs. It involves three general goals- pollution prevention at the end of a product's use, product stewardship to minimise the environmental footprint during use and clean technologies that reduce the use of polluting materials and develop environmentally friendly competencies (Hart, 1997).

There are a number of measures of Greenness. The four most common ones are *reduction in e-waste, reduction in energy consumption, reduction in Green House Gas Emissions and reduction in water (*Walley & Taylor, 2005; Hart, 1995). These measures are not necessarily mutually exclusive and are indeed interrelated. We argue that the primary motivation of Greenness should focus on one or more of these four areas without recourse to economic impact. Nevertheless, we also recognise that reduction in waste, energy and water can reduce cost, improve employee morale and create a Green brand equity and differentiation (Mathur & Mathur, 2000; Porter & Van der Linde, 1995). We refer to this coincidence as Green economic rent. The locus for Greenness ranges from the IT artefact through the IT department, the wider enterprise and supply chain to the economy. Likewise, the context for Greenness could cover either a full life cycle (creation, sourcing, operation, and disposal) or just one dimension only.

An analysis of existing "Green IT" literature (Table1) demonstrates that in a significant number of cases, while the terminology of Green or sustainability is mentioned, the goal of Greenness is absent. In addition, the locus for Greenness has not always been clear and has not often focused either on the IT artefact or the IT department. Rather it is loosely defined within the wider organisational context. Further, very few adopt a lifecycle assessment approach and most tend to focus either on the use or disposal dimension.

Like Green, the concept of IT is equally ambiguous. Some IT researchers distinguish between information technology (*IT*) and information systems (*IS*). In such distinctions, IT is limited to the asset based hardware and software technology resources that capture and process information whereas IS is referred to the more comprehensive mixture of IT, capabilities and organisational assets that enable IT to support individual, group and business goals (Wade and Hulland, 2004; March and Smith 1995). The IT infrastructure and capability perspective (Broadbent and Weil 1997; Byrd and Turner, 2000; Ravichandran and Letwongsatien 2005) and the IT metacategories (Orlikowski and Iacono, 2001) are relevant frameworks in understanding the IT artefact in the emerging Green IT literature.

Table 1: Representation of "Green" in the Green IT Research

Reference	The Goal of Greenness						The Locus for Greenness						The Context of Greenness				
	E-waste	Emission reduction	Energy efficiency	Water reduction	Green economic value	Nominal	IT Artefact	IT Department	Wider Enterprise	Supply Chain	IT Industry	Economy	Creation	Sourcing	Operation	Disposal	Not specifc
Dewick et al 2004						X			X								X
Brown et al 2005						X											X
Elliot 2007	X	X					X					X			X	X	
Elliot and Binney 2008		X						X	X						X	X	
Fuchs 2008												X			X		
Maruster et al 2008									X								X
Schmidt et al 2008						X							X	X	X	X	
Chen et al 2008					X				X								X
Murugesan 2008		X					X				X		X	X	X	X	
Molla et al 2008	X		X				X	X	X					X	X	X	
Molla 2008	X		X				X	X						X	X	X	
Capra and Merlo 2009			X				X						X				
Jenkin and McShane 2009						X			X								X
York et al 2009						X			X								X
Jenkin et al 2009	X								X								X
Daly and butler 2009			X						X						X		

Previous IT infrastructure research distinguishes between *the technical IT infrastructure* from the *IT human* and *managerial capability infrastructure.* The IT technical infrastructure is conceptualized as a pyramid of four layers: the network critical physical infrastructure (e.g. cooling, ventilating and power delivery); IT network and communications technologies (e.g. physical servers and network devices); shared service*s* (e.g. enterprise-wide databases and electronic data interchange (EDI); and business applications that utilise the shared infrastructure (e.g. sales analysis, purchasing) (Broadbent and Weil 1997). The IT *human infrastructure* pertains to "the experiences, competencies, commitments, values and norms of the IT personnel delivering the IT products and services" (Byrd and Turner, 2000). The *managerial capability* comprises the management of all IT activities including strategic foresight concerning changes in the business, IT and wider environment (Ravichandran and Letwongsatien 2005). While the IT infrastructure classification offers the ordering of the IT artefact within an organisational context, Orlikowski and Iacono's (2001) five metaconcepts of IT explain how the IS research community conceptualises the IT artefact. Orlokowski and Iacono (2001) developed the five metaconcepts of IT as *tool view, proxy view, ensemble view, computational view and nominal view*.

The tool view refers to the IT technical infrastructure and represents the engineered artefact. Orlikowski and Iacono (2001:123) found that the tool view has manifested in IS research in "four different ways-as a tool for labour substitution, a tool for enhancing productivity, a tool for information processing, and a tool for changing social relations". *The proxy view* captures the critical aspects of IT through surrogate measures such as "individual perceptions, diffusion rates, or dollar spent". *The ensemble view* represents the "web of computing which includes the commitments, additional resources such as training, skilled staff, and support services and the development of organisational arrangements, policies and incentives to enable the effective management and use of new technologies" (Orlikowski and Iacono, 2001: 125). It focuses on the "ways in which technologies come to be developed…and on how technologies come to be used" (Ibid: 126). The *computational view* focuses on the "capabilities of the technology to represent, manipulate, store retrieve and transmit information, thereby supporting, processing, modelling or simulating aspects of the world" (Ibid: 127). It normally involves the development of algorithms and computational models. Lastly, the *nominal view* indicates where the IT artefact is neither described nor conceptualised nor theorised. In the nominal view, despite the use of the words IT or IS, IT does not constitute either a dependent or independent variable.

An analysis of the Green IT research using the IT metaconcept and IT infrastructure is summarised in Table 2. The result shows that in the majority of the studies, while the terms IT and IS are used, the emphasis is often focused on institutional forces, organisational motivations and user behaviours. This is similar to Orlikowski and Iacono's (2001) finding where out of 177 published articles, about 25% had a nominal view of technology. The tool view is the second dominant view in the current Green IT research. In those cases, the potential role of IT is discussed in terms of improving energy efficiency. This implies that in addition to Orlikowski and Iacono's four manifestations of the tool view, IT is taking a fifth dimension as a tool for improving energy efficiency and reducing CO2 emissions.

In terms of the elements the IT infrastructure under consideration, most appears to focus on the application layer of the technical IT infrastructure. This corresponds to the prevailing tool view that most of the studies adopted. However, in more than 40% of the articles, the IT infrastructure under investigation or consideration is not clearly defined. Thus, a significant proportion of the existing Green IT articles have minimal engagement with the goals of Greenness, with the IT artefact and an organisation's IT infrastructure. Against the backdrop of the Green IT literature review, the next section presents a conceptual framework to overcome some, if not all, of the limitations of existing Green IT research in the future.

Table 2: Representation of the IT Artefact in Green IT research

Reference	Conceptualisation of the IT Artefact					Element of IT Infrastructure Under Consideration						
	Nominal	Computational	Tool	Proxy	Ensemble	Physical	Netwrok and communications	Shared services	Applications	Human	Mangerial	Not specifc
Dewick et al 2004					X							X
Brown et al 2005	X								X			
Elliot 2007	X						X		X			
Elliot and Binney 2008	X											X
Fuchs 2008			X									X
Maruster et al 2008	X							X	X			
Schmidt et al, 2008	X							X				
Chen et al. 2008			X						X			
Murugesan, 2008			X			X	X					
Molla et al 2008			X			X	X	X	X		X	
Molla 2008				X		X	X	X	X		X	
Capra and Merlo 2009		X							X			
Jenkin and McShane 2009				X								X
York et al 2009	X											X
Jenkin et al 2009			X									X
Daly and butler 2009					X							X

CONCEPTUAL FRAMEWORK

Green IT is the main construct of interest in this research. The review of existing Green IT literature in the previous section demonstrates that the construct has often been used loosely. For the purpose of this paper, the combination of the IT infrastructure (Byrd and Turner, 2000; Broadbent and Weil, 1997) and eco-sustainability (Hart 1995) perspectives can led to the following definition of Green IT

> *Green IT is a systematic application of ecological-sustainability criteria (such as pollution prevention, product stewardship, use of clean technologies) to the design, production, sourcing, use and disposal of the IT technical infrastructure as well as within the human and managerial components of the IT infrastructure in order to reduce IT, business process and supply chain related emissions, waste and water use; improve energy efficiency and generate Green economic rent.*

On the basis of this definition, the domain construct of Green IT can cover two dimensions. On the one hand, it reflects the amount to which a company factors in environmental considerations in IT from creation through sourcing and operations to end-of-life. This dimension of Green IT will be referred here as *"Green IT Reach"*. On the other hand, the maturity of environmental considerations, whether they're part of a coherent set of IT management policies, they've been adopted into the IT human and managerial operational routines and practices, or been built into concrete information systems and technologies represent another dimension. This second dimension will be referred here as *"Green IT Richness"*. At least three components of Green IT Richness could be identified – policy, practice and technology. The practice dimension is an element of the IT human infrastructure and captures the proxy view of IT. The policy dimension is an element of the IT managerial capability infrastructure and influences the creation and use of IT, thus reflects the ensemble view. The technology dimension is an element of the IT technical and physical infrastructure and falls under the tool and computational metacategories of IT.

The combination of *Green IT Reach and Richness* can yield into a matrix as depicted in Table 3. The matrix implies 12 possible domains of the Green IT construct. Maturity in Green IT Reach and Richness can demonstrate the strength of a firm's Green IT strategy and commitment to the main goals of Greenness- *reduction in e-waste, reduction in energy consumption, reduction in green house gas, reduction in water* and its ability to generate economic rent out of Green IT initiatives.

PRELIMINARY VALIDATION OF THE FRAMEWORK

In order to validate the Green IT Reach-Richness Framework, we draw from a survey data collected from 143 CIOs and Senior IT managers in early 2009 from three countries- Australia, New Zealand and USA. The sample frame was drawn from IncNet Australia (for Australia and New Zealand sample) and Top Computer Executives Directory (for USA Sample). The purpose of the survey was to examine the diffusion of Green IT and therefore precedes the full development of the Green IT Reach and Richness Matrix. Nevertheless, the instrument had a total of six policy, 17 practice and 20 technology related questions. There were no questions measuring the creation context of Green IT and the technologies and systems cells of sourcing and disposal. All questions used a seven point Lickert scale with labels anchoring the extreme points. Policy questions were measured on the scale of 1=not at all developed to 7= extremely well developed. Practice and Technology questions were measured on the scale of 1=not at all to 7= great extent. The 44 items are listed in appendix one.

Table 3: The Green IT Reach-Richness Matrix

Green IT Reach Dimensions	Policies	Practices	Technologies and systems
Creation	IT architectural policy that proactively consider environmental resource constraints along with more traditional IT business goals.	Practices in IT architectural power management capacity planning techniques to optimise operational processes and facilities design.	Green IT physical and technical infrastructure design. New algorithms that improve efficient usage of shared resources, lower CPU usage and lower energy consumption and measure GHG.
Sourcing	IT organisation's adoption of environmentally preferable IT purchasing policy and articulation of clear Green guidelines for buying IT equipment and services.	The practice of analysing the Green track record of software and IT services providers, incorporating Green considerations in vendor evaluation and IT procurement decisions	Information systems that track, monitor and analyse the carbon footprint of suppliers such as supplier sustainability assessment tools.
Operations	Encompasses the extent to which the services provided by the IT infrastructure support issues encapsulated in business sustainability. Some of the policy considerations include PC power management; policy on staff computer usage and Green data centres	Green IT operation practices refer to eco-considerations in operating the IT and network critical physical infrastructure in data centres and beyond and operational actions designed to improve the energy performance of corporate IT assets	New technologies and systems for (a) reducing the energy consumption of powering and cooling corporate IT assets (such as data centres) (b) optimizing the energy efficiency of business and supply chain operations (c) reducing IT induced greenhouse gas emissions (d) supplanting carbon emitting business practices and (e) analysing a businesses total environmental footprint.
Disposal	End of IT life management policy	Reuse (extend life), refurbish, recycle or dispose IT hardware	Information systems that track the life-cycle of corporate IT assets and analyse the cost-benefit of different disposal methods.

Most of the respondents (83%) in the data are CIOs or IT managers (systems, infrastructure, and information). While 69% classify their organisational size as medium and 24% as large. In terms of industry distribution, manufacturing, government and services sectors constitute 21%, 16%, 13% respectively. Forty one percent of all respondents operate IT shops with less than 50 servers, 20% between 50 and 150 and 34% more than 150 servers. Further descriptive results of the sample and the diffusion rate of Green IT are reported in Molla et al (2009).

Principal component analysis (PCA) is used in order to identify underlying constructs and condense the items used to assess Green IT. The objective is to identify latent dimensions that operationalise the proposed framework (Hair et al, 2006). Consistent with the exploratory nature of the study, the factors are extracted using an iterative sequence based on the principal component extraction technique. Using the Green IT Richness dimension as conceptual foundation, the items are put into the PCA in three separate models. Before running PCA, item reliability is assessed in order to remove "garbage items" and purify the measures (Churchill, 1979). Garbage items are items that do not share a common underlying construct but that tend to produce additional dimensions in a factor analysis. To purify the measures, analysis is run for each of the policy, practice and technology dimensions. Items with item-scale correlation less than 0.5 or whose correlations produce a substantial or sudden drop in the plotted pattern and which raise the alpha if deleted are eliminated. The cut-off

(0.5) is judgemental and Churchill's (1979) suggestion is to eliminate items with item scale correlation "near zero". As a result of the measure purification process, a total of Four items (5J, 5M; 6B, 6F) are deleted (two from practice and two from technology).

The three PCA models satisfy the minimum required sample size to item (observation) ratio of 5:1 (Hair et al, 2006:112). To facilitate interpretability, varimax rotation is followed. In view of the data reduction and summarisation objective of the analysis, the criterion used to assign an item to a factor was a minimum factor loading of 0.5. In each cycle of the iteration, only factors with eigen values greater than one are retained. In addition, in order to increase discrminant validity, items that cross-load on two factors with factor loading greater than 0.4 are eliminated from subsequent iterations. For the sake of parsimony, single item factors are also excluded. As a result of this process, a total of five items (5D, 5E, 5O, 6S, 6T) are dropped.

The policy component analysis produces one Green IT Policy (GITP) factor composed of 6 items. The Green IT practice model returns three factors containing 12 items. The first component captures the use of IT in monitoring energy consumption and environmental footprint and is labelled as Green IT measuring and monitoring practice (GITMP). The second component reflects the application of environmental consideration in IT sourcing decisions and is labelled as Green IT sourcing practice (GITSP). The third component refers to operational practices in reducing the energy consumption of the IT technical infrastructure and is labelled as Green IT energy efficiency practice (GITEFP). The technology component model returns two factors with 16 items. The first factor contains technologies that reduce power consumptions in lighting, power delivery and cooling of data centres and is labelled as Green IT network critical physical infrastructure (GITNCPI). The second component consists of technologies that improve the environmental value of servers, storage and network devices and is labelled as Green IT technical infrastructure (GITI). All four models are valid because each model explains more than 60% of the variance and there is no single factor that accounts for more than 50% of the variance in a given model (Hair et al, 2006). To assess reliability, Cronbach alpha is calculated. All but one of the scores pass the stringent reliability score of 0.80 widely accepted in IS research. The final factor structure of the Green IT construct is depicted in Table 4.

To assess discriminant validity the correlation between all pairs of the constructs is calculated. All the correlations were below the threshold value of 0.90 (Hair et al, 2006). The square root of the variance extracted was greater than the correlations of the constructs (Table 5). Hence, the reliability and validity of the constructs are acceptable. The correlation coefficient between the six factors is positive and significant (Table 5). The magnitude is stronger between Green IT measuring and monitoring practice(GITMP) and the other Green IT dimensions. This implies that an initial power emission and power utilisation audit might be associated with the development of Green IT policies, the adoption of Green IT practices and the implementation of Green technological initiatives or vice versa.

THEORETICAL IMPLICATIONS

The importance of Green IT is strongly recognised in practitioner literature. Likewise, the IS research community has started investigating Green IT as an important research agenda. Nevertheless, Green IT research has yet to make it to the leading IS journals and most of the existing articles come from conference proceedings. By all account, Green IT research is a nascent but growing area of research. For the Green IT research to have usefulness, there should be a clear conceptualisation of its domain constructs. The advance of Green IT research field, like other research fields, requires theorisation, model construction, and measurement development (Hair et al. 2006). This is because "theory construction and a cumulative tradition, the ultimate objectives of a research field, are inseparable from measurement" (Byrd and Turner 2000:192).

Using theoretical insights from the eco-sustainability and IT infrastructure literature, a comprehensive conceptualisation of Green IT has been proposed. Further, 12 possible classifications of Green IT has been identified. The principal component analysis has provided preliminary empirical support for the classifications of Green IT and the Green IT Reach-Richness framework. Table 6 maps the variables identified through principal component analysis against the proposed framework.

The definition of Green IT satisfy the guidelines for a good definition as it clearly state the "genus (the type of thing defined) and differentia (what distinguishes it from others of the same genus)" (Pankaj et al. 2009: 22). The definition further has conceptual clarity and offer details of specific variables, elements, or components (for example those covering the goal of Greenness, the IT infrastructure locus and the lifecycle context) – additional qualities of a good definition (Byrd and Turner 2000; Pankaj et al. 2009). The proposed Green IT Reach-Richness framework represents an original contribution to the information systems literature. Researchers can use the framework to clearly define the Green IT research phenomenon they intend to investigate.

Table 4: Green IT Factor Structure: Validity, internal consistency and reliability

Factor	ID	Factor Loading	Inter Item Correlation	Cronbach Alpha	Mean	Std. Dev
GITP	Q4E	0.87	0.80	0.925	3.57	1.46
(Green IT Policy)	Q4F	0.89	0.83			
	Q4G	0.90	0.84			
	Q4H	0.88	0.81			
	Q4I	0.71	0.61			
	Q4J	0.88	0.82			
GITMP	Q5C	0.67	0.61	0.83	2.72	1.27
(Green IT	Q5K	0.70	0.66			
Monitoring Practice)	Q5P	0.70	0.60			
	Q5L	0.76	0.62			
	Q5I	0.79	0.69			
GITSP	Q5N	0.70	0.57	0.84	4.28	1.42
(Green IT	Q5Q	0.71	0.61			
Sourcing Practice)	Q5A	0.84	0.73			
	Q5B	0.86	0.79			
GITEFP	Q5H	0.72	0.58	0.7	4.55	1.33
(Green IT Energy	Q5G	0.79	0.72			
Efficiency)	Q5F	0.85	0.64			
GITI	Q6A	0.76	0.63	0.86	4.36	1.38
(Green IT Technical	Q6C	0.84	0.73			
Infrastructure)	Q6D	0.73	0.66			
	Q6E	0.76	0.73			
	Q6G	0.73	0.64			
GITNCPI	Q6H	0.68	0.72	0.92	3.19	1.38
(Green IT Network	Q6I	0.72	0.72			
Critical Physical	Q6J	0.77	0.70			
Infrastructure)	Q6K	0.71	0.71			
	Q6L	0.71	0.71			
	Q6M	0.78	0.70			
	Q6N	0.76	0.68			
	Q6O	0.63	0.61			
	Q6P	0.67	0.65			
	Q6Q	0.65	0.62			
	Q6R	0.78	0.77			

Table 5: Correlations

	GITP	GITEEF	GITSOP	GITI	GITNCPI	GITMP
GITP	1					
GITEEF	.470**	1				
GITSOP	.711**	.450**	1			
GITI	.464**	.516**	.357**	1		
GITNCPI	.582**	.443**	.444**	.566**	1	
GITMP	.722**	.501**	.531**	.575**	.668**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6: Empirical Support for The Green IT Reach-Richness Framework

		Green IT Richness		
		Policy	Practice	Technology/Systems
	Creation	--	--	--
Green IT Reach	Sourcing	GITP	GITSP	---
	Operation		GITEEF GITMMP	GNCPI GITI
	End-of-Life		---	---

PRACTICAL IMPLICATIONS

The results of the study have also practical implications. The *Green IT Reach-Richness* framework can indicate different strategic trajectories in Greening IT. It can be used to assess both the breadth and depth of Green IT adoption. The Reach and Richness of Green IT among organisations can be hypothesised to range from low to high. High Green IT Reach can be associated with the adoption of Green IT covering the creation, sourcing, operation and end-of-life IT management. Low Green IT Reach can be associated with initiatives that focus on one dimension of the life cycle only. Where as high Green IT Richness refers to the maturity of Green IT policies, practices and technologies, low Green IT Richness refers to low maturity. Mapping the high-low Green IT Reach against Green IT Richness yields four possible strategic options for practitioners as depicted in figure 1.

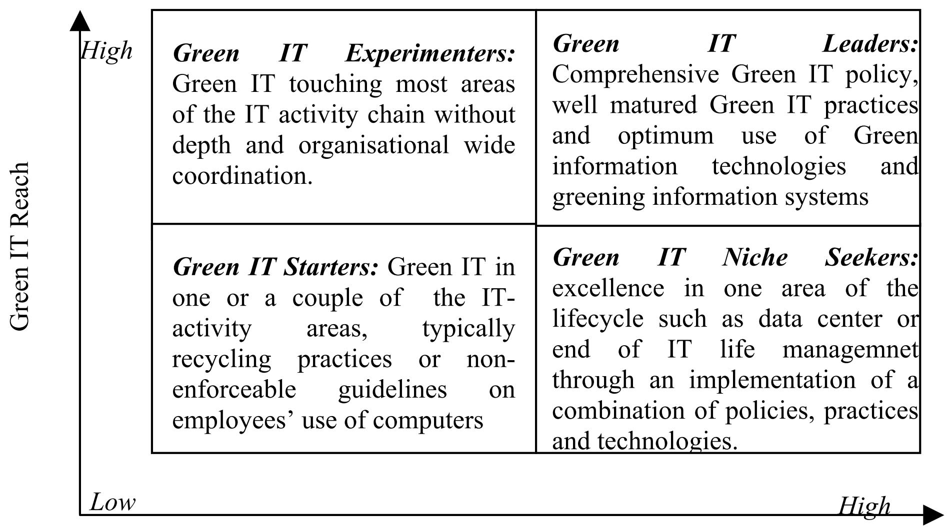

Figure 1: Strategic Options in Green IT

CONCLUSION AND LIMITATIONS

Although "Green IT" is becoming more common in discussion, there is still little common understanding of the domain constructs of Green IT. Clear definition of a construct is an essential first step to progress in theorisation. There might not be an absolute "Green IT Artefact". Green is relative and should be conceptualised in terms of the goals of Greenness. This paper identified five such gaols as emission reduction, waste reduction, energy efficiency, water reduction, Green IT economic rent. The IT artefact should also be defined clearly. Orlikowski and Iacono's (2001) IT metacategories and the IT infrastructure perspectives offer useful insights in conceptualising the IT in the Green IT research. An analysis of the existing Green IT academic articles indicates that often both Green and IT are treated nominally with researchers alluding to some undefined concept of sustainability and IT artefact. This raises serious question as to what IT brings to Green and vice versa.

Using the goals of Greenness, the IT metacategories and IT infrastructure perspectives, this paper proposes a Green IT Reach and Richness framework. By drawing from an existing data and analysing it through PCA, the paper empirically identifies six constructs of Green IT reflecting some of the Green IT Reach and Richness intersections indicating the validity, albeit preliminary, of the proposed framework. The framework has both theoretical and practical implications as discussed in the previous sections. However, the study is subject to several limitations. First, data are collected prior to the full development of the framework. Second, the data are collected from a relatively small sample size. Third the identified constructs are not tested for confirmatory validity. Fourth, the instrument is biased towards the problem side of the IT-sustainability equation and more needs to be done to capture the role of IT in solving sustainability issues. These limitations suggest areas for future research and improvement of the framework. A purpose-built instrument with adequate face validity can lead to better opertionalisation of the Green IT Reach-Richness framework and identification of the Green IT constructs with clear specifications of both the "Green" and the "IT" and with adequate content of IT as causing and solving eco-sustainability problems. Future research can also build conceptual frameworks that explain antecedents and consequents of Green IT. This study has taken the first step and other researchers can use the results of the study to refine the definition and develop theories of Green IT.

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Appendix A: Initial Instrument
Initial Items for Policy Construct
Seven point scale anchored by 1= Not at all developed and 7= Extremely well developed

4E	Environmentally friendly IT purchasing policy
4F	Green data centres policy
4G	Policy on the use of IT to reduce the business's carbon footprint
4H	Policy on employees use of IT in an energy efficient manner
4I	End of IT life management
4J	Green information technology policy

Initial Items for Practice Construct
Seven point scale anchored by 1= Not at all practiced and 7= Practiced to a great extent

5A	Preference of IT suppliers that have a green track record
5B	Gives weight to environmental considerations in IT procurement
5C	Shortens IT equipment refresh periods to gain access to more energy efficient equipment
5D	Considers environmental factors in the design of the site infrastructure (lighting, power delivery, cooling systems) & IT infrastructure (servers, storage and network)
5E	Audits the power efficiency of existing IT systems and technologies
5F	Switches off data centre lights and equipment when not needed
5G	Operates existing IT systems in an energy efficient manner
5H	Enforces PC power management
5I	Implements IT projects to monitor the enterprise's carbon footprint
5J	Prints double-sided on paper
5K	Analyses IT's energy bill separately from the overall corporate bill
5L	Relocation of its data centre near clean sources of energy
5M	Recycles consumable equipment (e.g. batteries, ink cartridges, and paper)
5N	Disposes of IT equipment in an environmentally friendly manner
5O	Uses electricity supplied by green energy providers
5P	Engages the service of a professional service provider regarding Green IT
5Q	Prefers hardware vendors that offer end of IT life "take-back" options

Initial Item Measures for Technology Construct
Seven point scale anchored by 1=Not at all and 7=Great Extent

6A	Server consolidation and virtualisation
6B	Desktop virtualisation
6C	Storage virtualisation
6D	Data de-duplication
6E	Storage tiering
6F	Print optimisation
6G	Rightsizing IT equipment
6H	Data centre airflow management
6I	Free cooling in large scale data centres
6J	Water cooled chillers with variable speed fans and pumps
6K	Hot aisle/cool aisle data centre layout
6L	Upgrades to more efficient transformers and UPS
6M	Airside/waterside economizer
6N	Liquid cooling for IT equipment
6O	Install more energy efficient lights
6P	High voltage AC power
6Q	DC powered IT equipment
6R	High efficiency stand-by power systems
6S	Retire energy inefficient systems
6T	Computers that have functions to shut down components when unused

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